Energy, Mines and Resources Canada
Énergie, Mines et Ressources Canada

CANMET

Canada Centre for Mineral and Energy Technology
Centre canadien de la technologie des minéraux et de l'énergie

REVIEW OF CUTTING TECHNOLOGY FOR EVAPORITE MINING

G. Knight
Canadian Mine Technology Laboratory

JUNE 1987

This document is an unedited interim report prepared primarily for circulation and internal reference purposes. It does not represent a final expression of the opinion of the Canada Centre for Mineral and Energy Technology (CANMET).

Ce document est un rapport intérimaire non-révisé et rédigé principalement pour fin de circulation et de documentation interne. Il ne représente nulle-ment l'opinion définitive de CANMET (Centre canadien de la technologie des minéraux et de l'énergie).

11 pp

MINING RESEARCH LABORATORIES
DIVISION REPORT MRL 87-148 (IR)

MICROMEDIA

Review of Cutting Technology for Evaporite Mining

G. Knight *

ABSTRACT

This report outlines the relationship between potentially-airborne dust generation and cutting technology. The important factors in cutting to minimize dust are: maximum depth of cut; lacing optimized to produce maximum breakage to free surface; pick shape to optimize chip formation; pick mounts to minimize interference in chip clearance and secondary crushing; and cutter trajectory to maximize proportion of cutting at optimum cutting depth, that is to minimize shallow cutting during entry. The major limiting factor to cutting speed and productivity is bit temperature; an overheated bit wears rapidly. The value of water in cutting is fivefold: it improves crack propagation; clears chips away from the tool; reduces pick forces; cools the pick and binds the fine, potentially-airborne, dust to the coarse to reduce subsequent dispersion into the air.

This report reviews cutting and dust control technology and outlines a program for a study to improve the techniques used in evaporite mining.

---

* Research Scientist Canadian Mine Technology Laboratory,
Mining Research Laboratories, CANMET,
Energy, Mines and Resources Canada. Ottawa, Ontario.

KEYWORDS: Evaporite mining, Cutting parameters, Dust control

INTRODUCTION

Many authors have found correlations between the amounts of fine potentially airborne dust produced in cutting coal and rock with the cutting parameters (1-5). Some have also found that a correlation exists between dust generation and energy input. Major advances have been made in reducing specific dust generation and specific energy input in coal cutting operations through the application of developments in cutting technology (6-10). It should be noted that improved cutting technology has been a major factor in achieving acceptable dust conditions on coal faces, with productivities as high as a 1000 tonnes per shift.

Advances made in coal cutting technology cannot be applied directly to evaporite cutting because of their different rock parameters. Evaporites have a very much lower tolerance to water and its use to achieve dust control and cutting enhancement is limited.

The mechanisms of rock cutting and dust dispersion have been reviewed(11,12). Two major forms of cutting action are described as indentation and wedge or cleavage . In indentation, such as roller cutters, the normal force predominates, whereas in wedge cutting with a sharp bit the cutting or parallel force predominates. In both cases a compressive force is applied to the rock through the cutting tool which produces a crushed region. Tensile stresses established by the cutting tool in the surrounding region lead to crack propagation and chip formation. In general, the bigger the chips the lower is the specific energy required for cutting and the amount of primary fine dust produced.

The production of fine dust and its dispersion into the air should be considered as a result of the following sources and processes:

1. Primary dust is that produced directly by the tool during cutting and can be considered as the result of three processes as follows:
    (a) Produced in the crushed zone adjacent to the pick
    (b) Produced by breakage in the propagating crack induced by tensile failure
    (c) Dust already present as in slip planes
2. Secondary dust is that produced when the broken rock is broken further by being trapped between moving and stationary parts of the machine or rock prior to loading and transport.

3. Direct dispersion during breakage. Strain energy is released at breakage, some of this is transferred to kinetic energy of the breakage fragments and they can be projected into the airstream.

4. Tumbling and windmilling of the broken rock and machine components can disperse some of the already formed fine dust into the air.

Local airflows play a very important part in the dispersion of dust. In coal mines a substantial airflow is usually required to dilute methane gas and reduce the possibility of ignitions. However, in evaporite mines, there is a much lower possibility of gas emissions and the reduction of local airflows should be considered such as using shrouding or cowls.

Water has been shown to give substantial advantages in rock cutting such as: increases in crack propagation; clearing chips from the cutting zone and reducing energy input and dust formation; reducing pick forces during cutting; cooling the pick and, lastly, reducing dust dispersion into the air by binding fine potentially-airborne dust particles to coarser non-dispersible fragments (13). Water has had limited use in evaporite mines for dust control but not apparently for maximum improvement in cutting (14,15).

It is also possible that the presence of water improves the transmission of stress from the tool to the rock and reduces the amount of crushing occuring before and during crack propagation to form a chip. The consensus of opinion is that water should be fed to the pick as close as possible to the cutting face of the tool.

The objectives of the cutting in evaporite mining studies are:

1. Reduction in airborne dust

2. Reduction in energy consumption

3. Reduction in other costs

4. Increase in productivity

The studies are likely to lead to a change in particle size distribution of the output with fewer fines and more coarse breakage fragments. This change is expected to improve ore handling characteristics in storage bunkers and chutes.

TEST METHODS

The United Kingdom National Coal Board used a number of test rigs in its experimental work at the Mining Research Establishment(16). These were a single pick rig, two small milling cutters to simulate the Anderton shearer, and a full size single or multiple pick test rig. Further development work was carried out with full size machines on simulated coal (cast concrete) at the Swadlincote test site of the Central Engineering Establishment (16).

The U.S. Bureau of Mines used various single and multiple pick test rigs at its Twin Cities Research center as well as much field work(7). They developed an instrumented portable full size single pick test unit for use at the coal face in the mine(17,18). An improvement could well be the additional measurement of the side force to improve understanding of the break-out to two open faces.

Most of these methods are capable of estimating the engineering parameters of cutting alone, especially when the unit is instrumented for the measurement of pick forces. However, they cannot be expected to resolve all the problems such as secondary crushing, pick temperature and pick wear. Further studies will be required to determine the limits on pick speed as set by temperature rise and wear.

WATER USAGE

It is clear that the use of water in cutting has great advantages in both cutting and in dust control. However, there are major possible problems in using water in evaporite mines as it might lead to a breakdown in the transport system by fusing lumps of the soluble ore together or to excessive corosion. It seems to be absolutely necessary that any usage of water in the evaporite mines would have to be very carefully controlled (15,19). Possibly the amount that could be applied to the ore could not exceed that lost by evaporation during transport on the conveyor belts etc.. It would seem desirable to carry out preliminary wetting experiments at a site where excess water would not cause a major problem.

The evaporation of dust control water might not nullify the effect because the fine potentially airborne dust particles could have fused to the coarser fragments and thus not be available for subsequent dispersion as at transfer points.

DISCUSSION AND RECOMMENDATIONS

The evaporite mines have used available coal cutting machines, often with modification (20,27). The major emphasis has been on larger, more powerful and more flexible machines. Generally, however, the mines do not meet the suggested dust control standard of 10 mg of total dust per cubic metre of air in the cutting and transport regions(28). The standard of $10mg/m^3$ is based on safety (visibility) and comfort (chafing) as well as health effects. Thus the argument of no health effects at the existing higher concentrations is not a valid reason for ignoring the existing standard. The required dust control could be met by dust suppression with water as in the hard rock or coal mines, but this would probably lead to insurmountable problems in transport. Dust control by air extraction and/or filtration is technically feasible but expensive. Improvement in cutting technology appears capable of solving the dust problem whilst, at the same time, improving productivity and reducing specific energy consumption and other costs. Possibly the increase in product size and reduced fines content could also lead to fewer problems in transport and decreased mill losses.

It is suggested that research and development into cutting in evaporite mines should proceed as follows:

1. Borrow or build an instrumented test rig for a full size single pick similar to the U.S.B.M. test rig(17,18). The instrumentation should include measurement of force in all three directions: normal, cutting and side.
2. Study cutting parameters in dry conditions:
    (a) compare U.S. point shape picks with the European wedge shapes,
    (b) cutting depth
    (c) pick spacing
    (d) first cut (one open face) and subsequent cuts (two open faces)
    (e) pick size
    (f) angles between wedge or point picks and rock face when cutting to two open faces
3. Study of the effect of using small quantities of water on pick forces and dust control.

(a) water feed position – three possibilities: pointed to rock just ahead of pick, pick face flushing or through pick

4. The effects of small quantities of water on the ore handling system together with the water losses during transport along a conveyor or other system.

5. Studies on full size system applying the research to the fullest extent possible.In particular the lacing and speed limit as given by cutter temperature and wear should be assessed.

The shape of the picks used should, in the first instance, reproduce modern practise in the European and U.S. hard coal mines (29-31). The european wedge shape pick has as its main advantage a lower cutting force when sharp but the cutting force increases as the pick gets blunt. The american rotating point attack pick has as its main advantage only a slight increase in cutting force as it gets blunt and a longer life.

One factor that appears to have been partially overlooked in the development of cutting machines is maximum utilization of the two free faces which can be present– one of these faces was cut by the pick on its last traverse and the one just cut by the adjacent leading pick as shown in figure. When using a chisel shaped pick the angled position rather than the normal square setting might take better advantage of the two free faces which can be made available. If this is true it will affect the leads of all the picks and the layout of the picks such that each cut uses the cut face from the leading pick and cuts a face for the following pick as shown in figure 1.

It is noted that the "Improved Cutting System Design" by the U.S.B.M., while maintaining a constant depth of cut through most of the cut, has all the picks in line and, presumably, does not take maximum advantage of the two free faces that could be made available(32).

REFERENCES

1. **Roepke W.W., D.P. Lindroth, and T.A. Myren:** Reduction of Dust and Energy During Coal Cutting Using Point-Attack Bits *Report of Investigations 8185*. U.S. Dept. of the Interior. U.S.B.M. Washington (1976)

2. **Black S. and R.L. Schmidt:** Effect of Continuous Miner Parameters on the Generation of Respirable Dust. *Min. Cong. J. 64*. 19-25(1978)

3. **Hanson B.D. and W.W. Roepke:** Effect of Symmetric Bit Wear and Attack Angle on Airborne Respirable Dust and Energy Consumption. *Report of Investigations 8395*. U.S. Dept. of the Interior. U.S.B.M. Washington (1979).

4. **Roepke W.W. and B.D. Hanson:** Testing Modified Coal-Cutting Bit Designs for Reduced Energy, Dust, and Incendivity. *Report of Investigations 8801* U.S. Dept. of the Interior, U.S.B.M (1983).

5. **Roepke W.W., C.F. Wingquist, B.D. Hanson, and L.S. Sundae:** Research on Reducing Generation of Primary Respirable Dust in Cutting Coal. In *Coal Mine Dust Conference Proceedings*. S.S. Peng(ed) West Virginia U. Morgantown (1984).

6. **Anon:** The MRE Large-Pick Shearer Drum. *MRE Bulletin No.9* NCB Mining Research Establishment Isleworth England. (1966).

7. **Roepke W.W. and K.C. Strebig:** Coal Cutting Technology: A Study of field studies at Twin Cities Research Center. Presented at *Coal Cutting Technology and Dust Reduction Seminar*. NCB MRDE Bretby England (Dec 1980)

8. **Zibelius G. and S. Frigge:** Effects of Cutter-Pick Design and Lacing on the Winning Performance of a Drum Shearer Loader. *Gluckauf and Translation 118* 186-188 (1982)

9. **Anon.:** Basic Principles of Coal Cutting. *MRE Bulletin No.7* NCB Mining Research Establishment Isleworth England. (1965).

10. **Singh S.P.:** Brittleness and the Mechanical Winning of Coal *Mining Science and Tech. 3* 173-180 (1986)

11. **Stecklein G., R. Bransteller, R. Arrowood, D. Davidson, J. Lankford, R. Lyle and C. Nulton:** Basic Research on Coal Fragmentation and Dust Entrainment. *U.S. Dept. of Commerce NTIS*. (1983)

12. **Roepke W.W.:** General Methods of Primary Dust Control During Cutting. *Mining Eng. 36*. 636-644 (1984).

13. **Hood M.:** Waterjet-Assisted Rock Cutting Systems– the Present State of the Art. *Internat. J. of Mining Eng. 3* 91-111 (1985).

14. **Grigal D.J., M.D. Blom and D.F. Johnson:** Dust Control for Cutter Machines. *U.S. Dept. Commerce, NTIS No. 82-202706.* (1981)

15. **Page S.J.:** Controlling Salt-Mine Cutting Machine Dust with a Low-Flow foam technique. *Technology News* p213 (dec 1984)

16. **Hamilton R.J., J.S. Barker, et. al.** *NCB MRE and NCB CEE internal reports* Isleworth and Bretby England (1960-1965)

17. **Church J.C.:** Device for In-Situ Measurement of Coal-Cutting Forces *R.I. 8925* U.S. Dept. of the Interior USBM, Washington. (1985)

18. **Roepke W.W. and J.C. Church:** Measuring In-seam Coal Cutting Forces *Min. Eng. 35* 1281-1286 (1983).

19. **Page S.J., C.W. Urban and J.C. Volkwein:** Effectiveness of Wet Cutter Bars in Reducing Salt Mine Dust *R.I. 8512* U.S.Dept. of the Interior USBM., Washington (1981)

20. **Permiakow R.S.:** Mining Systems and Mechanization in Potash Ore Mines of the USSR. In *7th International Mining Congress* Bucharest (1972)

21. **Haryett C.B.:** Innovations over the Last Decade in the Saskatchewan Potash Industry. *Min. Eng. 34* 1225-1227 (1982)

22. **Lucazeau C.:** Continuous Miners in the Potash Mines of Alsace. *Industrie Min., Les Techniques.* 603-620 (1982).

23. **Greif R. and M. Streckenfinger:** On the Subject of Cutting Extraction in French Potash Mining. *Erzmetall 36* 111-117 (1983).

24. **LeBeque M.K. and J. Karlovsky;** The History and Evolution of Boring Machines into the Potash Industry. In *Proc. 1st International Potash Technology Conf.* R.M.McKercher (ed) pp225-232 Saskatoon (1983)

25. **Kogelmann W.J.:** Recent North American Advances in Boom-type Continuous Miners for Potash. In *Proc. 1st International Potash Technology Conf.* R.M. Mckercher(ed) pp231-238 (1983)

26. **Scales M.:** Orebiter Speeds Potash Extraction at Lanigan Mine. *Can. Min J. 104/12* 17-19 (1983).

27. **Newman J.H. and D.H. Scotney:** Overcutting at Roof Level at the Winsford Rock Salt Mine. *World Mining Equipment 8/5* 62-65 (1984).

28. **Anon;** Threshold Limit Values and Biological Exposure Indices 1986-1987 . *Am. Conf of Gov. Ind. Hyg.* Cincinnati USA. (1986).

29. **Hurt K.G. and D.D. Laidlaw** Laboratory Comparison of Three Rock Cutting Tools *Tunnels and Tunnelling 13-6* 13-15 (1979)

30. **Ford L.M. and M. Friedman** Optimization of Rock-Cutting Tools Used in Coal Mining *in Proceedings of the 24th U.S. Rock Mechanics Symposium* C.C. Mathewson(ed).Texas A& M University (1983)

31. **Hurt K.G. and K.M. MacAndrew** Cutting Efficiency and Life of Rock-Cutting Picks *Mining Sc. and Technology 2* 139-151 (1985)

32. **Roepke W.W. and S.J. Anderson:** Triangular Shaped Cutting Head for use with a Longwall Mining Machine. *U.S.Patent No. 4 303 277* (1981)

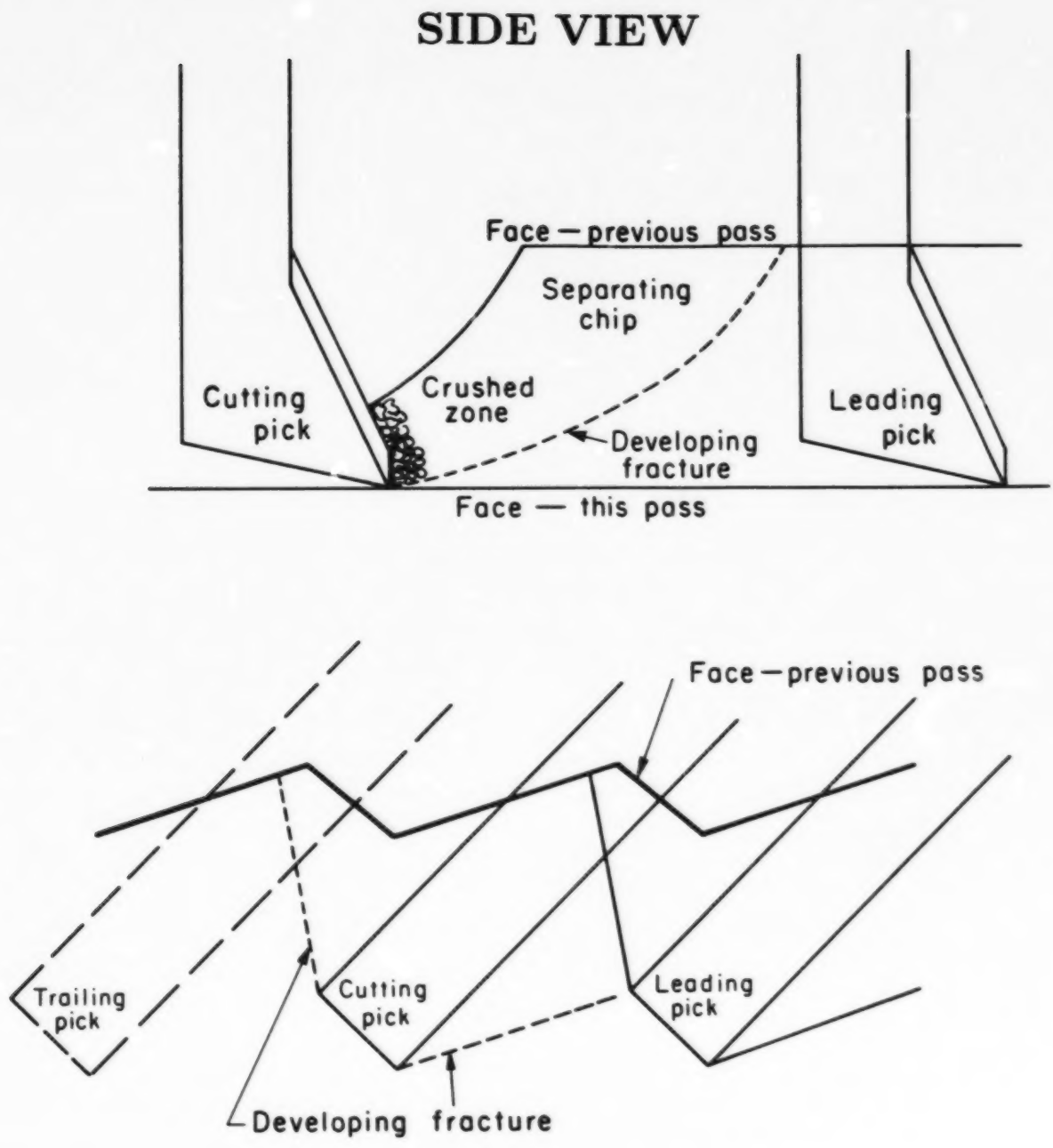

Fig. 1 Layout of picks taking advantage of two open faces showing developing fractures